Frequency Analysis of the Vibration of Tread Brake Dynamometer for the High Speed Train

Min-Soo Kim, Jeong-Guk Kim, Byeong-Choon Goo, and Nam-Po Kim
Vehicle Dynamics & Propulsion System Research Department
Korea Railroad Research Institute
360-1 Woram-dong, Uiwang-si, Kyonggi-do
KOREA
ms_kim@krri.re.kr http://www.krri.re.kr
jkim@krri.re.kr
bcgoo@krri.re.kr
npkim@krri.re.kr

Abstract: - This paper deals with the frequency analysis of the abnormal vibration of the specific speed range when the tread brake test is applied in the brake dynamometer. Generally brake system of railway vehicles has a crucial role for the safety as well as riding quality of passengers. And dynamometers are widely used to simulate and test the vehicle brake system performance including the emergence brake. Experiments on the brake dynamometer for the high speed train are provided to illustrate the frequency analysis of the abnormal vibration in vehicle speed at 140 [km/h] and 70 [km/h] under the 920 [mm] wheel diameter using the 3-axis accelerometers.

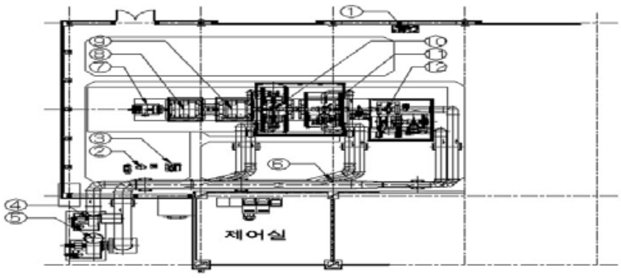
Key-Words: - Tread Brake, Brake Dynamometer, Railway Vehicle, 3-Axis Accelerometers

1 Introduction

The first dynamometer was designed to measure the brake horsepower of a motor. This invention was the work of an engineer, Gaspard. He invented the Prony Brake Dynamometer in 1821 in Paris. Variations of this dynamometer are still in use today.

In general, dynamometers are widely used to simulate the break performance of the railway vehicle. An example of such a dynamometer is shown in Figure 1. There are many variations to this basic format, because of the high speed rotation operation. There is an electric motor inserting and absorbing power, an inertia section, and a test section where the brake is mounted. Each size of vehicle will require different amounts of inertia. Since these disks are in discrete steps, there is often a compromise among the number of disks and wheels, the changeable inertia. Many test procedures specify how much inertia should be used based on vehicle weight and wheel load.

The test procedures performed on the brake dynamometers cover a wide range of operational conditions. They may simulate actual vehicle operations. For instance, in aircraft dynamometers it is typical to simulate actual operating conditions including taxing, take-offs, and landings. In passenger vehicle testing, standard procedures are often used which do not simulate typical vehicle operations, but instead, represent critical operational scenarios that test the limits of brake performance or elicit a specific type of performance characteristic.



No.	Component	No.	Component
1	Lubrication equipment	7	DC Motor
2	Pneumatic equipment	8	Flywheel A
3	Oil pressure equipment	9	Flywheel B
4	Air supply fan	10	Tread break equipment
5	Air ventilation fan	11	Disk break equipment
6	Air duct		

Fig.1 Drawings of the brake performance dynamometer

This paper contains the frequency analysis of the abnormal vibration in vehicle speed at 140 [km/h] and 70 [km/h] considering the 920 [mm] wheel diameter based on the 3-axis accelerometers.

This paper is organized as follows. Section 2 overviews a brake dynamometer. Section 3 describes the experiment environment for the tread brake for analyzing the abnormal vibration when the tread brake is applied. Section 4 shows the experiment results. The main conclusions are then summarized in section 5.

2 Brake Dynamometer

A dynamometer consists of the following main elements.

◆ The drive-train consists of the following elements: motor, interchangeable flywheels and brake disk. The flywheels and brake disk is matched to the part number to be tested.

◆ The test bed consist of the following elements: caliper & adapter, power transfer axle, load bearing arm and load cell to calculate the breaking force.

Brake dynamometer is designed to simulate the brake characteristic of the high speed train, and has a function of record the data which can be reproduced and help to analyze and compare the experimental object, and also is used to develop and test the brake system. The expected effect and practical scheme of the brake dynamometer are followings:

◆ Development of the brake, disk-pad, wheel and brake system of the high-speed & conventional train

◆ Test and performance evaluation of the brake system of the high-speed & conventional train with the international standard

◆ Performance and certification test of the brake system of the manufactured high speed train

Table 1 shows the main features of the brake dynamometer.

Fig.2 Brake performance dynamometer for high speed train

Table 1. Main performance of the brake dynamometer

Max. drive power	397kW(540HP)
Max. drive torque	2,527Nm (400km/h)
Max. drive speed	2,500rpm
Max. brake torque	25,000Nm
Pressure Brake	6,000 N x 2
Flywheel inertia	Max./Min. 1900kg·m²/400kg·m²
Diameter of the test wheel	Φ 700～1120mm
Acceleration time (0~1500rpm)	2 min. 30 sec

3 Experiments Environment

It was found from the results of the tread brake test appeared something abnormal vibration in the range of the vehicle speed at 140 [km/h] (i.e. about 808 [rpm]) and 70 [km/h] (i.e. about 404 [rpm]) considering the 920 [mm] wheel diameter. Therefore, we examined the frequency analysis on the axle and the brake block using the 3-axis accelerometers.

Fig. 3 shows the abnormal vibration phenomenon of the tread brake torque in the range of the vehicle speed at 140 [km/h] (i.e. about 808 [rpm]) and 70 [km/h] (i.e about 404 [rpm])

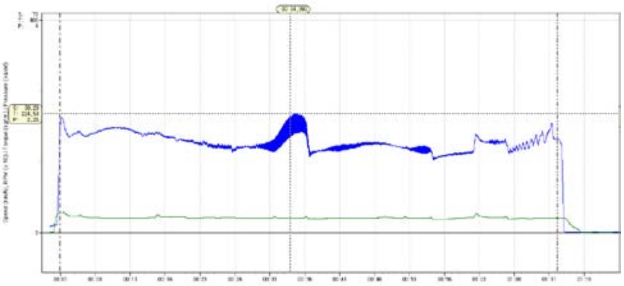
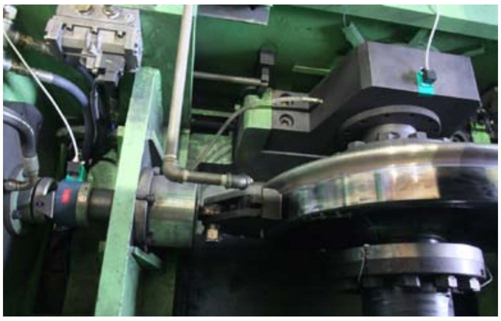


Fig.3 Torque and pressure brake of tread brake



(a) Position of the 3-axis accelerometers

(b) DAQ system

Fig.4 Measurement system for the brake experiment

In the tread braking test of the brake dynamometer, the initial test speed is set out at 270 [km/h] with composite tread brake blocks for the high speed train.

Fig. 5 shows the transition of the vehicle speed from 270 [km/h] to 0 [km/h].

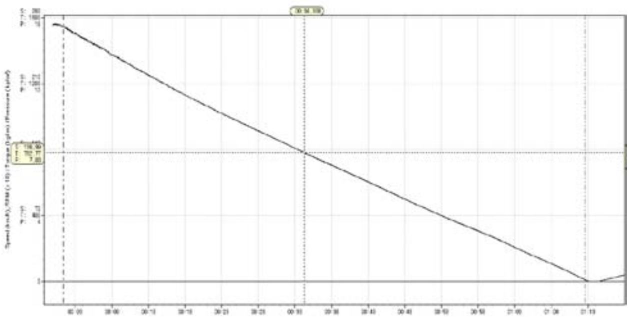


Fig.5 The change of the vehicle speed at 270 [km/h]

The inertia value was chosen 800 [kg·m^2] because the UIC test program prescribed 4 [ton] (mass per brake disc) in case of the high speed train. And cylinder force is accomplished under 5.9 [KN].

4 Experiments

The measuring signals for analyzing the vibration of the axle and brake block using the 3-axis accelerometers are transmitted to the DAQ via A/D converter, and the frequency analysis is performed.

Fig. 6 shows the experimental results about the full measurement data including the braking images installed with the 3-axis accelerometers on the axle and its frequency analysis at 134 [km/h].

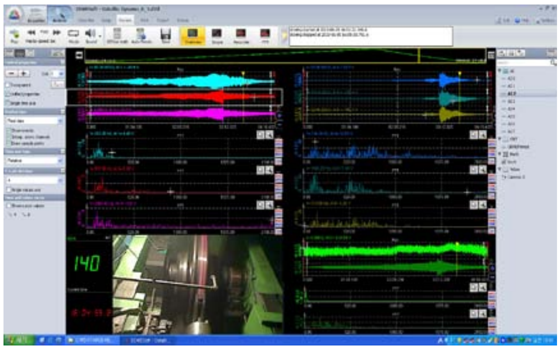
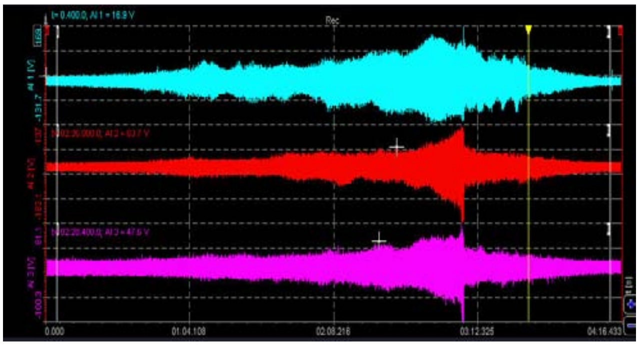
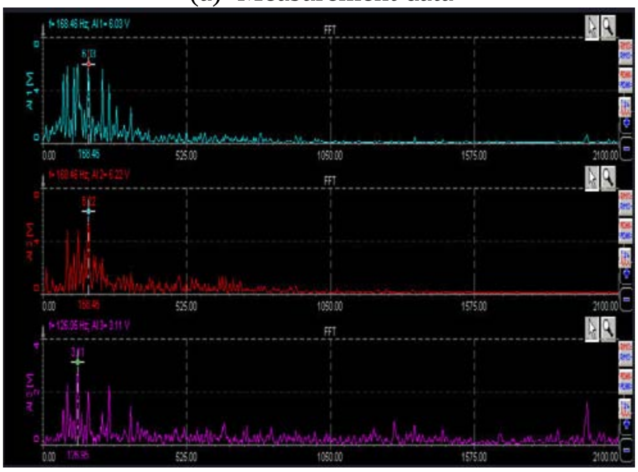


Fig.6 The DAQ system for the abnormal vibration analysis



(a) Measurement data



(b) Frequency analysis

Fig.7 Measurement data with the 3-axis accelerometers on the axle and its frequency analysis at 134 [km/h].

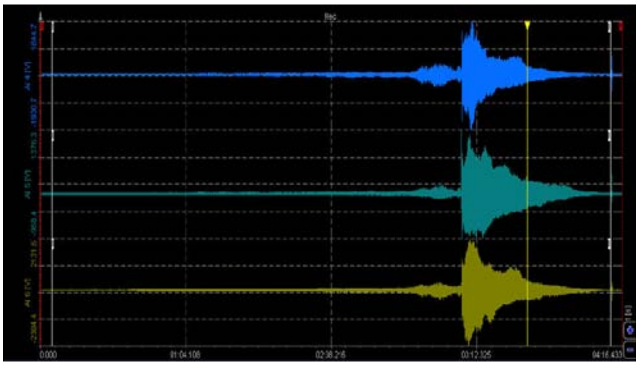
Main frequencies of the measurement data of the 3-axis accelerometer on the axle at 134 [km/h] are shown in Table 2.

Table 2. Main frequencies of the measurement data of the 3-axis accelerometer on the axle

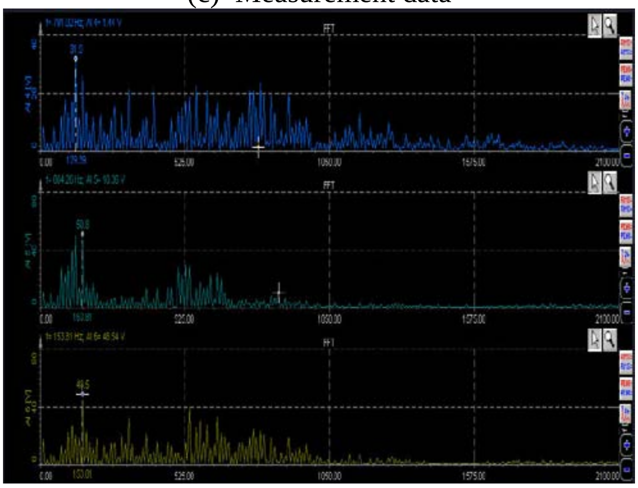
Axis	Frequency [Hz]	Voltage [V]	No.

x-axis	78.125	5.25	6
	90.332	5.82	3
	114.75	5.67	4
	126.95	5.97	2
	168.46	6.03	1
	219.73	5.62	5
	244.14	4.41	7
y-axis	90.332	4.87	2
	129.39	4.83	3
	168.46	6.22	1
z-axis	90.332	2.23	2
	126.95	3.11	1
	166.02	1.93	4
	244.14	2.02	3

Fig. 8 illustrates the measurement data with the 3-axis accelerometers on the brake block and its frequency analysis at 134 [km/h].



(c) Measurement data



(d) Frequency analysis

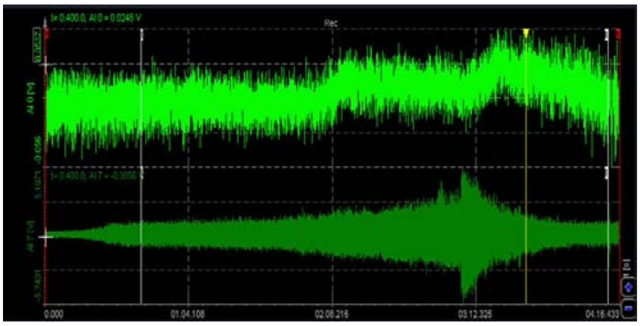
Fig.8 Measurement data with the 3-axis accelerometers on the brake block and its frequency analysis at 134 [km/h].

Main frequencies of the measurement data of the 3-axis accelerometer on the brake block at 134 [km/h] are shown in Table 3.

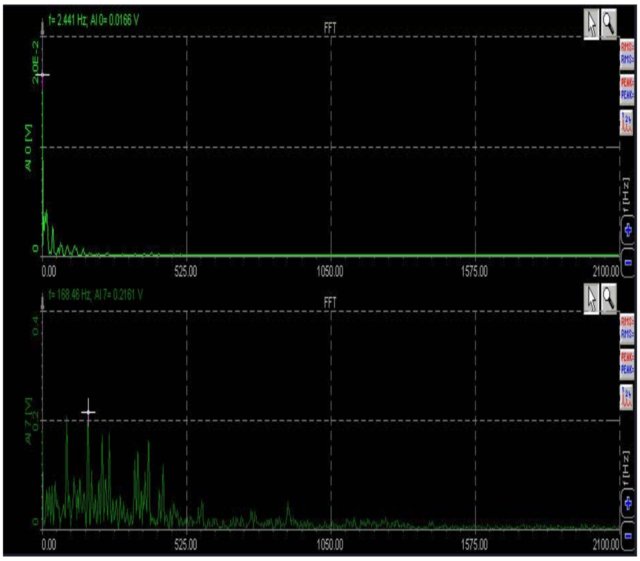
Table 3. Main frequencies of the measurement data of the 3-axis accelerometer on the brake block

Axis	Frequency [Hz]	Voltage [V]	No.
x-axis	90.332	17.84	10
	129.39	31.92	1
	153.82	25.74	2
	271.00	15.58	12
	322.27	21.28	6
	412.60	21.56	5
	539.55	15.84	11
	566.41	22.97	4
	605.47	20.55	8
	761.72	18.89	9
	773.94	20.81	7
	790.34	23.52	3
y-axis	129.39	49.34	2
	153.81	50.77	1
	529.79	26.10	3
z-axis	153.81	48.54	1
	322.27	32.10	3
	541.99	39.52	2

The displacement of x-axle and braking noise using the laser sensor and the micro phone, respectively, and its frequency analysis at 134 [km/h] are shown in Fig. 9.



(a) Measurement data



(b) Frequency analysis

Fig.9 Measurement data with the axle displacement and braking noise, and its frequency analysis at 134 [km/h].

Main frequency of the displacement of x-axle is 2.441 [Hz] and those of the braking noise are 168.46 [Hz], 90.332 [Hz], 244.14 [Hz], and 219.73 [Hz] . These two frequencies (168.46 [Hz], 90.332 [Hz]) have coincidence between the braking noise and measurement data of the 3-axis accelerometers on axle at 134 km/h.

5 Conclusion

In this paper, we present a tread brake experiments on the dynamometer for high speed train in order to analyze the abnormal vibration in specific vehicle speed at 140 [km/h] and 70 [km/h]. For analysis we use the 3-axis accelerometers on the axle and on the brake block. As a result of the analysis we could verify the mutual action between axle vibrations and the brake block connection with the brake cylinder.

References:

[1] Simon Iwnicki, Handbook of Railway Vehicle Dynamic, CRC Press, 2006.

[2] Garg V. K. and Rukkipati R. V.,“Dynamics of Railway Vehicle Systems,” Academic press, 1994.

[3] UIC CODE 541-4 Brakes – Brakes with composite brake blocks – General conditions for certification of composite brake blocks, 3rd Eds. May 2007.

[4] DEWESoft Tutorials - Data acquisition, processing analyzing and storage software, 2007.